International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:6, No:2, 2012

Correction of Infrared Data for Electrical Components on a Board

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***Abstract*—**In this paper, the data correction algorithm is suggested when the environmental air temperature varies. To correct the infrared data in this paper, the initial temperature or the initial infrared image data is used so that a target source system may not be necessary. The temperature data obtained from infrared detector show nonlinear property depending on the surface temperature. In order to handle this nonlinear property, Taylor series approach is adopted. It is shown that the proposed algorithm can reduce the influence of environmental temperature on the components in the board. The main advantage of this algorithm is to use only the initial temperature of the components on the board rather than using other reference device such as black body sources in order to get reference temperatures.

***Keywords*—**Infrared camera, Temperature Data compensation, Environmental Ambient Temperature, Electric Component

I. Introduction

THE temperature data obtained from infrared detectors are dependent on the surface temperature. The difficulties to handle this data lie in the nonlinear characteristics of detectors [1]-[3]. A conventional way of data correction in infrared camera is to use some target temperature source for compensation. As a target temperature source, thermal electric coolers or black body sources are often used. Using this source, a look-up table is established for compensation. In order to do this, an additional control system for temperature target sources is required.

In this paper, a simple correction algorithm is suggested. To correct infrared data, the suggested algortihm requires only the initial temperature or the initial infrared image data so that target source systems may not be necessary. In this paper, temperature variations for the working electrical components on a board are considered. The algorithm is designed based on the detector model[1-3] and the heat exchange model[4] between the electric components and the environmental air temperature.

The paper is organized as follows. The problem this paper considers is described in Section II. In Section III, a novel but simple compensation algorithm for infrared camera data is suggested based on thermal dynamic equations. The performance of the suggested algorithm will be investigated through experiments for electric components on board in Section IV. Finally, the conclusions are mentioned in Section V.

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II. Problem statement

In this section, the problem this paper considers is defined. The configuration of an electric board testing equipment using infrared camera consists of a infrared camera, power supply, measuring circuits and signal control units. The testing system is supplying electric power to a printed circuit board under test. Once the electric power is asserted to the board, electric components on the board are starting to work and the temperature of the surface of each component rises because of the power consumption. Fig. 1 shows the infrared images of PCB board which works well. The images are sampled every 30msec. Note that the temperatures of areas occupied by electric components are varying. In the figures, the temperatures are translated to colors and red color means high temperature and dark colors mean low temperatures. As you can see, the temperatures rise after the power is asserted to the PCB board under test. The testing system compares test images with reference normal images and decides whether the board is good or not. Even further, it can give informations about which device is not working well.

In Fig. 2, the infrared images of a PCB board which is not woriking well are given. Compared with Fig. 2, there are some different areas which show different and high temperatures in Fig. 2. It can be noticed that the electric components located at those areas have some problems because they showed quite different temperature variations as power was asserted. We found that those elements are power elements and so they showed quite high temperatures. Like this, a PCB board can be tested using infrared cameras when electric power is asserted. This kind of testing is called as power-on-test. If we can assign appropriate signals to each component and test a board, it is also called as functional test.

In this paper, we consider the temperatures of electric components working on a board. By observing temperature variations of electric components, we can decide whether the components on a board work well or not. When the power is asserted to the board, electric components are working and the power consumption causes the electric components to be heated. So, the performance of the electric component can be estimated by checking the profile of temperature variation of the electric component. The temperature of object surface can be measured by infrared cameras. However, environmental air temperature around electric component can have an influence on the temperature of the object surface.

(A) Infrared Image of Frame 1

(B) Infrared Image of Frame 200

Fig. 1 Infrared Images of good PCB Board under Test

Consider surface temperature variations of electric components working on a board. The equation which governs this can be described as follows using well-known Newton's law[4].

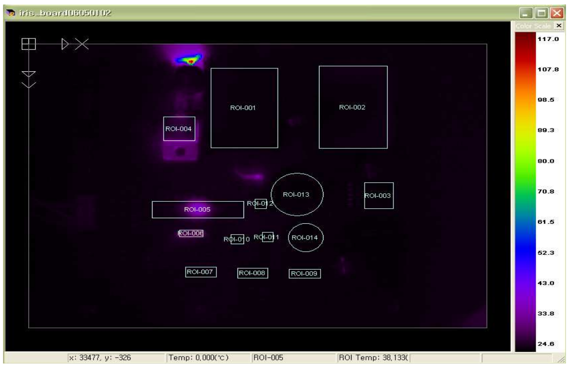
$$\frac{dT_C}{dt} = -K_C(T_C - T_B) + KP(t) \qquad (1)$$

where T_C is surface temperature of electrical component, T_B is the environmental air temperature, K_C is time constant of each electrical component and $P(t)$ is the input power applied to each component. From (1), the surface temperature of electrical component can be obtained as follows.

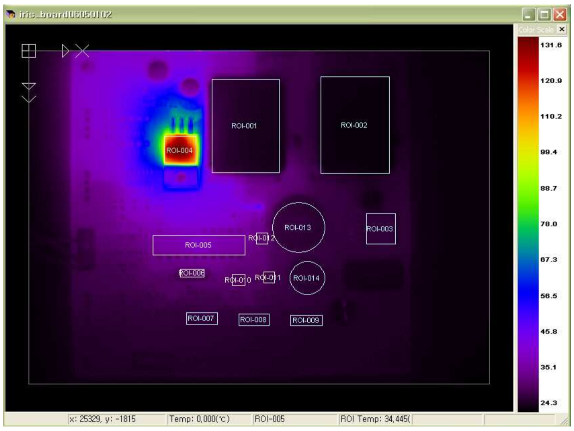
$$T_C(t) = T_C(0)e^{-K_C t} + T_B(1 - e^{-K_C t}) + \int_0^t e^{-K_C(t-\tau)} KP(\tau) d\tau \qquad (2)$$

Since the component's surface is in equilibrium state with the environmental air initially, the following assumption holds.

$$T_C(0) \cong T_B = \text{constant} \qquad (3)$$



(A) Infrared Image of Frame 1



(B) Infrared Image of Frame 200

Fig. 2 Infrared Images of bad PCB Board under Test

Using (3), the temperature of electric component's surface satisfies the following equation.

$$T_C(t) = T_C(0) + \int_0^t e^{-K_C(t-\tau)} KP(\tau) d\tau \qquad (4)$$

If the electric power supplied to electrical component during the period [0,t] is the same, then the same component should always show the same temperature variation due to this electric power. In other words, the following equation should hold.

$$\Delta T_C(t) = T_C(t) - T_C(0) = \text{constant} \qquad (5)$$

The infrared camera data can be interpreted using the following equation [1]-[3].

$$M_C(t) = \varepsilon_c \sigma T_C^4(t) + (1 - \varepsilon_c)\sigma T_B^4 \qquad (6)$$

where ε_c is the emissivity of each electric component and σ is Stephan-Boltzman constant. Since the data obtained from the infrared camera is nonlinearly dependent on the surface temperature of the object, even in the case of the same input electrical power, temperature variations show the difference depending on the different air temperatures around the electronic component. So, the algorithm which compensates this nonlinearity is required in order to improve the accuracy of infrared camera data. The problems considered in this paper are two-fold.

Firstly, it is required to find a compensation algorithm for infrared data which can compensate the influences caused by environmental temperature changes. Secondly, a measure is needed in order to decide whether electric component on board works well or not compared to normally good component. In the next section, a data compensation algorithm is proposed based on the equations described above.

III. Design of a Data Compensation Algorithm

Using (4) and Talyor series expansion, the following approximation holds.

$$T_C^4(t) = T_C^4(0) + 4T_C^3(t)|_{T_C(t)=T_C(0)}\, \Delta T_C(t) + O(\Delta T_C^2) \quad (7)$$

If $\Delta T_C(t)$ is assumed to be relatively small compared to $T_C(0)$, the approximation is quite well satisfied when the first two terms are taken in (7). From (6) and (7), the following approximation holds.

$$\begin{aligned} M_C(t) - M_C(0) &= \varepsilon_c \sigma [4T_C^3(0)\cdot \Delta T_C(t) + O(\Delta T_C^2)] \\ &\approx \varepsilon_c \sigma [4T_C^3(0)\cdot \Delta T_c(t)] \end{aligned} \quad (8)$$

This implies that the following approximation holds for $\Delta T_C(t)$.

$$\Delta T_C(t) = \frac{1}{4\varepsilon_c \sigma T_C^3(0)}[M_C(t) - M_C(0)] \quad (9)$$

As it is expected, the temperature variations $\Delta T_C(t)$ due to supplied electric power are dependent on the initial temperatures of electric component which are the same with environmental air temperatures. In order to implement (9), the information about the emissivity ε_C of each electric component is needed but it is not easy to get this information for various component materials.

In order to decide whether electric component on board works well or not compared to normally good component, a measure of error rate with respect to normal good component is introduced as follows.

$$E_{test} = 1 - \frac{\Delta T_{test}(t)}{\Delta T_C(t)} \quad (10)$$

where $\Delta T_C(t)$ is the temperature variation of normal good component and $\Delta T_{test}(t)$ is the temperature variation of an electric component under test. Using (6) and (9), $E_{test}(t)$ can be decribed as follows.

$$E_{test} \approx 1 - \frac{T_C^3(0)[M_{test}(t) - M_{test}(0)]}{T_{test}^3(0)[M_C(t) - M_C(0)]} \quad (11)$$

If we are interested in the behavior of an electric component on board compared with a good one, the value $E_{test}(t)$ can give an information to judge. If we use (11) for $E_{test}(t)$, the information about the emissivity of each electric component, ε_C, is not necessary, which is the main advantage of usage (11). In order to implement (11), the initial temperature data are required. From the assumption (3) and the equation (6), the following equation holds for t=0.

$$\frac{T_C^3(0)}{T_{test}^3(0)} = \frac{M_C(0)}{M_{test}(0)}\cdot\left(\frac{M_{test}(0)}{M_C(0)}\right)^{1/4} \quad (12)$$

Using (12), the equation (11) can be rewritten by

$$E_{test} \approx \frac{M_C(0)}{M_{test}(0)}\cdot\left(\frac{M_{test}(0)}{M_C(0)}\right)^{1/4}\cdot\frac{M_{test}(t) - M_{test}(0)}{M_C(t) - M_C(0)} \quad (13)$$

Note that the implementation of (13) requires only the infrared camera data, which is the main advantage of the proposed algorithm.

IV. Conclusion

In this paper, a compensation algorithm for infrared camera data has been suggested for the compensation of errors caused by different environmental ambient temperatures.

The compensation algorithm is using only the initial temperature of the object rather than using the reference temperature developed by thermal electric cooler system so that it does not require any additional system for the compensation.

Acknowledgment

This research was supported by Basic Science Research Program(No. 2010-0008915, 2011-0004506) and by Mid-career Researcher Program (No.2011-0013091) through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science, and Technology

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